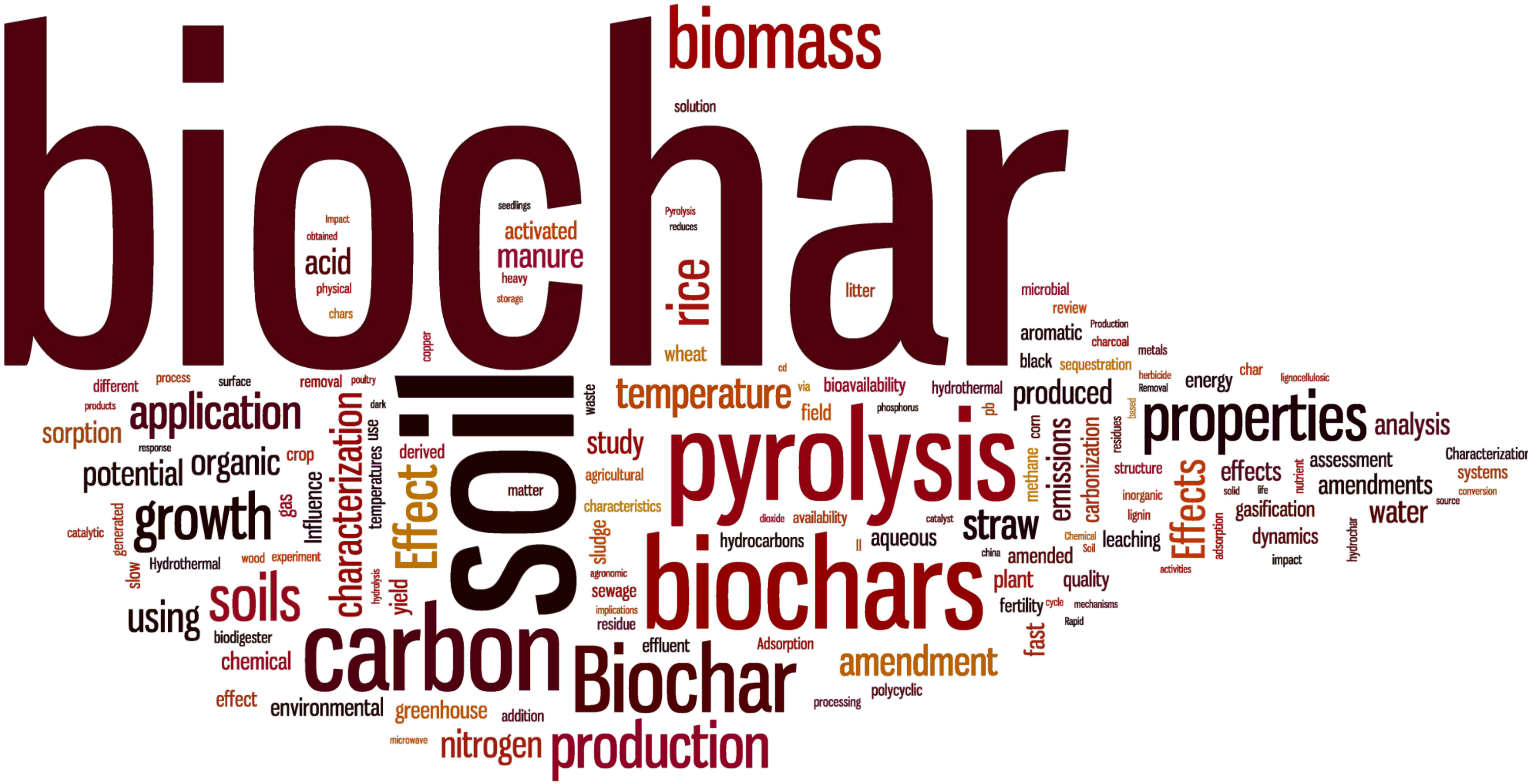
Biochar, soil, pyrolysis, carbon, and more

K. Thomas Klasson, Research Leader

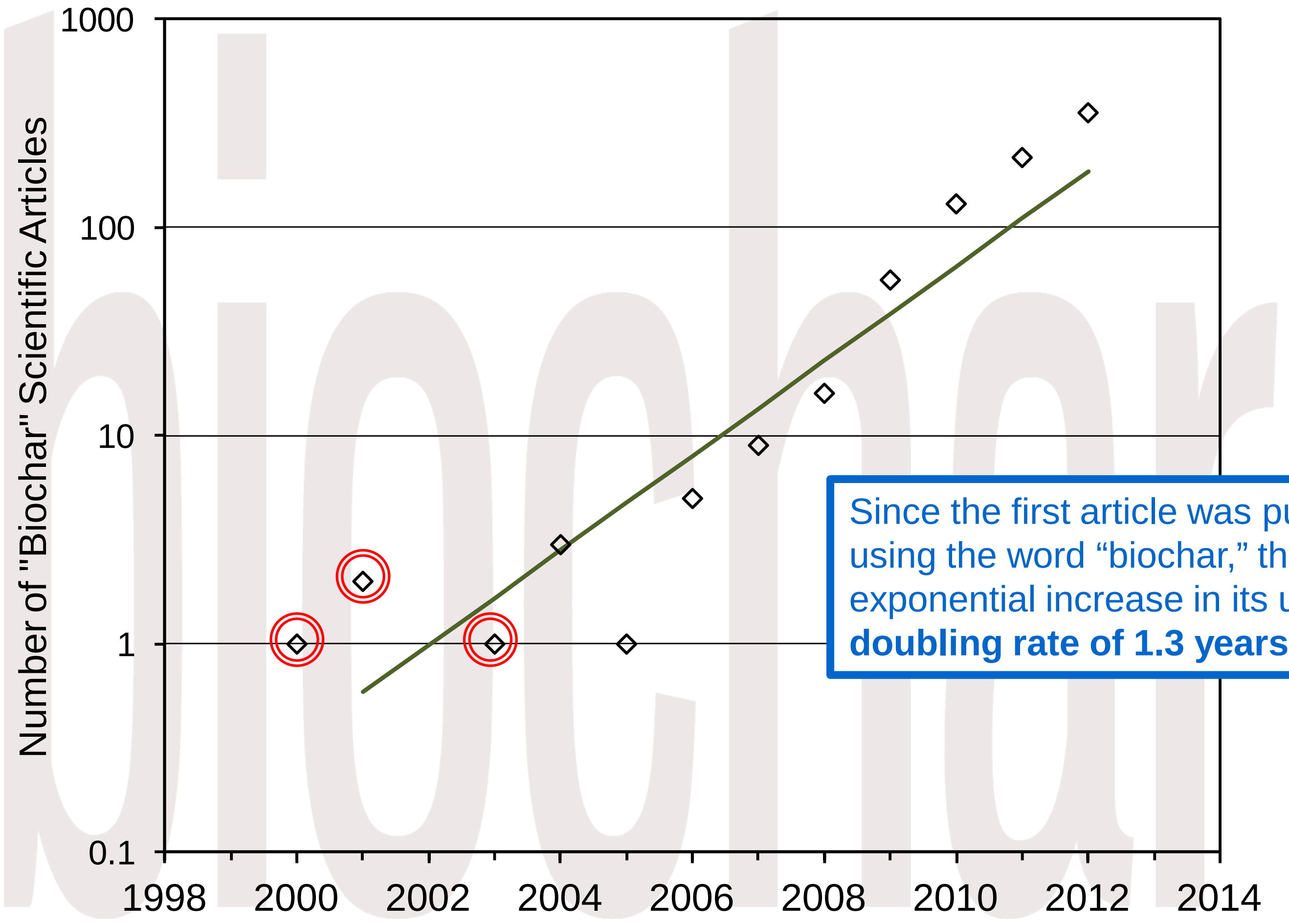
U.S. Department of Agriculture,
Agricultural Research Service,

New Orleans, LA 70124

Biochar, soil, pyrolysis, carbon, and more…..



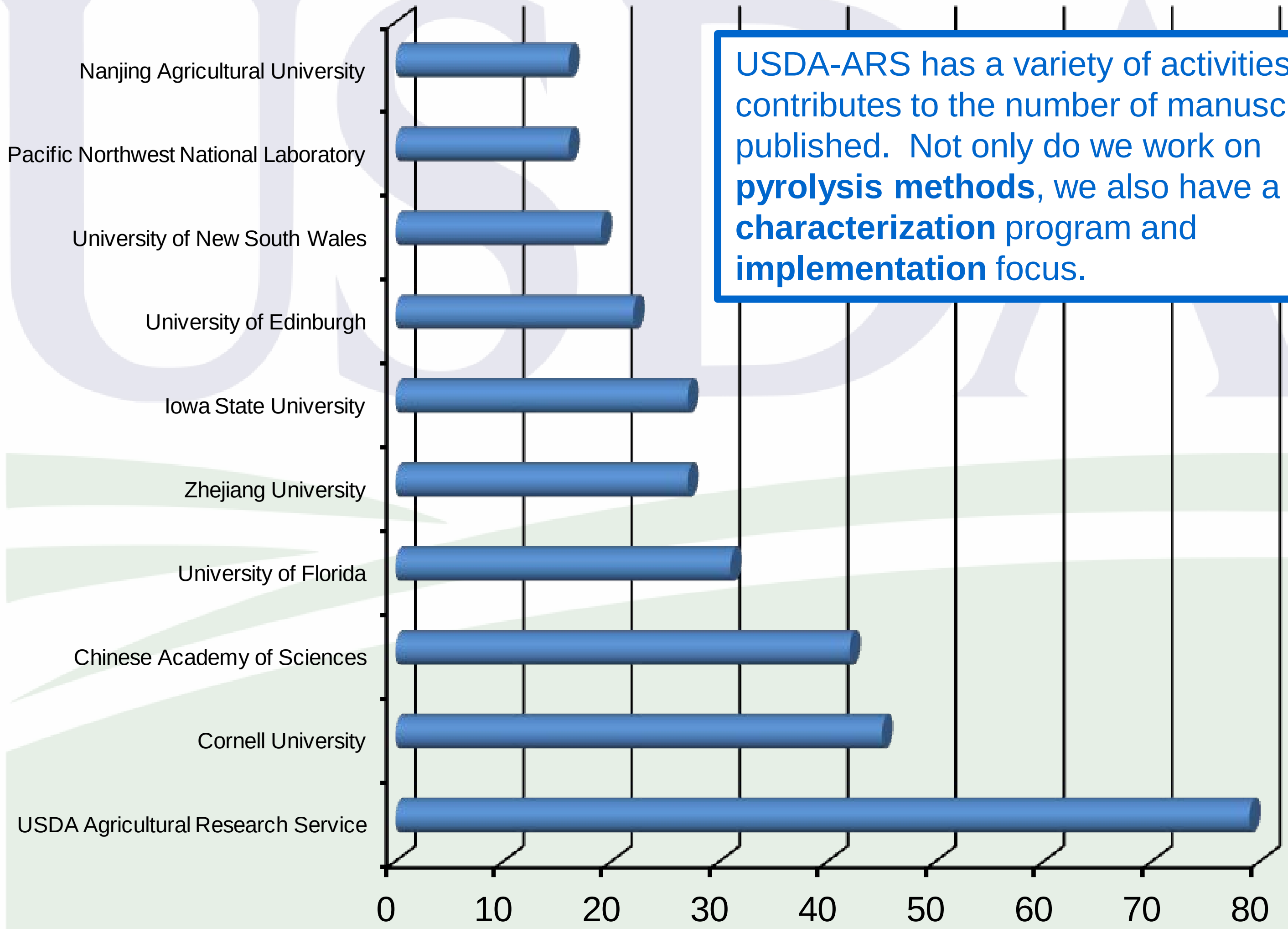
How much are we publishing ?



Since the first article was published in 2000 using the word “biochar,” the term has seen exponential increase in its use with a **doubling rate of 1.3 years**.

USDA

Who is publishing ?



USDA-ARS has a variety of activities that contributes to the number of manuscripts published. Not only do we work on **pyrolysis methods**, we also have a strong **characterization** program and **implementation** focus.

Surprisingly many books on the topic

The first publications on “biochar”

336 *Energy & Fuels* **2000,** *14,* 336–339

2000

Biochar from the Straw-Stalk of Rapeseed Plant

Filiz Karaosmanoğlu,*,† Aslı Işığıgür-Ergüdenler, and Aydın Sever†

Department of Chemical Engineering, Istanbul Technical University, Maslak-Istanbul 80626, Turkey

Received June 8, 1999. Revised Manuscript Received November 1, 1999

Agricultural residues are an important and inexpensive bioresource for energy production. In this study the slow pyrolysis technique has been applied to the straw and stalk of rapeseed plant, and the effects of temperature and heating rate on the yields and characteristics of the solid products (biochars) have been investigated. Experiments were performed in a tubular reactor under nitrogen atmosphere at constant heating rate (5 °C min^{-1}) and varying temperatures (400–900 °C) and at constant temperature (800 °C) and varying heating rates (5, 10, 15, °C min^{-1}). The biochars obtained are carbon rich, reactive, and relatively pollution-free potential solid biofuels.

The first publications on “biochar”

2001

Journal of Thermal Analysis and Calorimetry, Vol. 65 (2001) 147–152

THERMAL ANALYSIS OF CASEIN

Vol. 66 (2001) 743–748

Keywords: biochar, casein, pitch, pyrolysis

JOURNAL OF MATERIALS SCIENCE **38** (2003) 2347 – 2351

A biochar from casein and its properties

2003

B. PUREVSUREN, B. AVID
Institute of Chemistry and Chemical Technology, Mongolian Academy of Sciences, Ulaanbaatar-51, Mongolia
E-mail: b_avid@yahoo.co.uk

B. TESCHE
Max-Planck-Institut für Kohlenforschung, Elektronenmikroskopie Kaiser-Wilhelm-Platz 1, Mülheim an der Ruhr, 45470 Germany

YA. DAVAAJAV
Institute of Chemistry and Chemical Technology, Mongolian Academy of Sciences, Ulaanbaatar-51, Mongolia

A biochar was prepared by pyrolysis of casein. A helium and mercury porosimeter were used to measure the true and apparent densities of the chars respectively, elemental and IR analysis were used to characterize the chemical composition of char. A SEM was used to observe the char surfaces in order to verify the presence of porosity. The biochar has 9.02% of nitrogen, content of porosity is 20%. The experimental results show that it is possible to prepare chars with relatively high porosity from casein for the further preparation of activated carbon. © *2003 Kluwer Academic Publishers*

The first publications on "biochar"

Pergamon

Chemosphere, Vol. 39, No. 1, pp. 23-32, 1999

0045-6535/99/ $ - see front matter

PII: S0045-6535(98)00585-2

1999

An Activated Carbon Product Prepared from Milo (*Sorghum Vulgare*) Grain for Use in Hazardous Waste Gasification by ChemChar Cocurrent Flow Gasification

Harshavardhan Bapat and Stanley E. Manahan*
Department of Chemistry
123 Chemistry Building
University of Missouri-Columbia
Columbia, MO 65211 USA

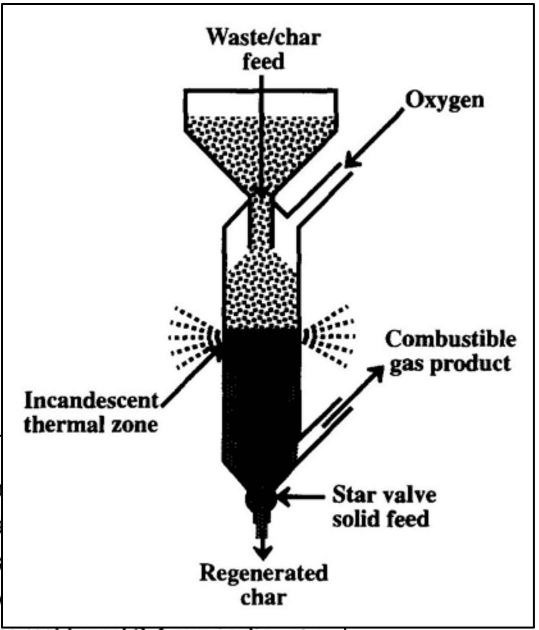
David W. Larsen
Department of Chemistry
University of Missouri-St. Louis
8001 Natural Bridge Road
St. Louis, Missouri 63121

(Received in Germany 12 August 1998; accepted 15 October 1998)

Abstract

An activated carbon was prepared by pyroly
gasification process. This carbon was charac
wastes and for sequestering metal bearing w

Although TRB char is a highly satisfactory material to use as a waste applications, in some cases a low-ash, low-sulfur alternative is desirable. In the research reported in this paper was conducted. The medium chosen as a c sorghum consisting of hard, round kernels of milo (*Sorghum vulgare*). This is the most common variety of sorghum grown in the United States, with abo from Texas, Kansas, Nebraska and Missouri. Milo produces a very hard spherical kernel 2-4 mm in diameter which has the properties needed to make a char and activated carbon useful for waste treatment. This paper describes the preparation and characterization of a low ash, low sulfur content, macroporous, moderately activated char made by the pyrolysis followed by gasification of milo grain. This material, called Milo Biochar, was tested as a waste carrier medium and fuel in the ChemChar waste gasification of selected organic compounds and wastes containing selected heavy metals.



The first publications on "biochar"

ELSEVIER

PII: S0016-2361(96)00151-2

Fuel Vol. 75, No. 15, pp. 1721–1726, 1996

0016-2361/96 $15.00+0.00

1996

Quantitative solid-state ^{13}C n.m.r. measurements on cokes, chars and coal tar pitch fractions

M. Mercedes Maroto-Valer, John M. Andrésen, J. Dilcio Rocha and Colin E. Snape
University of Strathclyde, Department of Pure & Applied Chemistry, Thomas Graham Building, 2
(Received

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(Keywords: ch

Table 1 Elemental analysis and ash content of samples investigated

	Temp. (°C)	Elemental analysis (wt% daf) C	H	N	(O+S)[a]	H/C	Ash (wt% db)
Coal	–	87.8	4.4	1.7	6.1	0.60	8.7
PCC-1	440	88.2	4.0	1.6	6.2	0.54	8.8
PCC-2	497	89.7	3.2	1.4	5.7	0.43	9.2
Bio-char	450	81.0	3.1	0.3	15.6	0.46	<0.1
CT-TI	–	92.1	2.7	0.9	4.3	0.35	n.d.[b]
CTP-TI	370	92.9	3.4	1.0	2.7	0.44	n.d.

[a] Estimated by difference
[b] Not determined

The first publications on “biochar”

Bioresource Technology **46** (1993) 23–29

1993

POWER-PRODUCTION OPTIONS FROM BIOMASS: THE VISION OF A SOUTHERN EUROPEAN UTILITY

G. Trebbi

ENEL S.p.A., Thermal and Nuclear Research Centre, Via Andrea Pisano 120, 56100 Pisa, Italy

Abstract

In the medium term, veg significantly in an envir the energy needs of the w progress of technologies use is achieved. In the promoted by the Comm munities (CEC), ENEL, authority, is contributing and development in the from biomass. The acti tests and several initiati and thermochemical co interest in this kind of e lined.

Key words: Energy crops able resources.

(typical values about 20%) and high investment (around UD$2500/kWe). Their use is only appropriate when low-price agricultural or forestry residues are available and/or the electricity selling prices are particularly high. A more interesting option would be combustion in large power stations with a capacity of more than 50 MW, with higher efficiencies ($\eta = 35$–40%) and loer specific investments. In this area, new fluidized-bed boilers are gradually substituting the old grate-combustion systems equipped with different kinds of fuel distributor; the steam conditions are also increased to improve the efficiency.

ENEL activities in this field are limited to the evaluation of the pneumatic transport of biomass powder to burners and to the preparation and testing of slurries obtained from powders or biochar mixed with water and/or bio-oil.

before inlet in the combustion chamber (regenerative cycle) or to produce steam that can be injected into the same GT (STIG cycle) or used to generate electricity through a steam turbine (combined cycle).

Preliminary firing tests indicated that the direct combustion of biomass powder is difficult owing to alkali evaporation and the subsequent condensation: heavy deposits were encountered downstream of the combustion camber. A possible solution to avoid this problem would be the introduction of an indirect combustor (slagging combustors or fluidized-bed combustors) fed by the exhaust from the turbine. When using sugar cane and sweet sorghum, this scheme could be modified by introducing a topper combustor (Fig. 1): the ethanol obtained by juice fermentation and the bagasse are burnt in the topper and bottom combustors, respectively.

Bio-Char Inc., 1984-2002

United States Patent [19]
Kerr

[11] **Patent Number: 4,723,494**
[45] **Date of Patent: Feb. 9, 1988**

[54] **INCINERATOR DISCHARGE SYSTEMS**

[75] Inventor: **Clifford G. Kerr,** Mississauga, Canada

[73] Assignee: **Anclif Equities Inc.,** Streetsville, Canada

[21] Appl. No.: **2,684**

[22] Filed: **Jan. 12, 1987**

[51] **Int. Cl.**[4] **F23G 5/00;** F23G 5/12; F23G 5/44

[52] **U.S. Cl.** .... **110/259;** 110/165 R

[58] **Field of Search** 110/259, 165, 168, 169, 110/210

[56] **References Cited**

U.S. PATENT DOCUMENTS

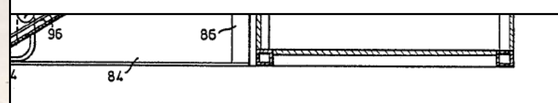
3,046,915 7/1962 Ludin .... 110/259 X

Primary Examiner—Edward G. Favors
Attorney, Agent, or Firm—Fetherstonhaugh & Co.

[57] **ABSTRACT**

A processor for processing the residue which is discharged from an incinerator comprises a receiver for receiving the residue and a discharge enclosure through

The reference numeral **10** refers generally to a processor constructed in accordance with an embodiment of the present invention. The processor **10** is used in association with an incinerator **12** which may be a batch incinerator of any conventional construction. A suitable ...esently manufactured by Bio-Char Inc. ... Churchill Blvd., Mississauga, Ontario, ...lentified as Bio-Char Model 4, Pryolysis ...inerator.



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What happened to Bio-Char Inc. ?

nended this 4th day of October 200x
odifie ce)suant to Rule 26.02(a)

egistrar - Superior Court of Justice
reffier - Cour Supérieure de Justice

Court File No.: 44544/06

ONTARIO
SUPERIOR COURT OF JUSTICE

B E T W E E N:

THE CORPORATION OF THE TOWN OF AJAX

Plaintiff

- and -

2047330 ONTARIO LIMITED and GORDON KERR

Defendants

13. The Plaintiff pleads that it did enter into a site plan agreement with Bio-Char, as contemplated, dated April 1, 1985 and a site plan was approved on June 6, 1985.

15. The Plaintiff pleads that Bio-Char subsequently changed its name to Ajax Energy Corporation and the change was registered on April 11, 2002.

16. The Plaintiff pleads that Ajax Energy Corporation subsequently changed its name to Energy Plus 2000 Limited on or about June 9, 2004.

35. The Plaintiff pleads that 2047330 Ontario Limited was incorporated on May 25, 2004.

What happened to Bio-Char Inc. ?

ONTA
SUPERIOR COUR

BETWEEN:

THE CORPORATION OF

- and

2047330 ONTARIO LIMITED and

AND BETWEEN:

2047330 ONTARIO LIN

- and -

THE CORPORATION OF THE TOWN OF AJA
and BOREALIS INFRASTRUCTURE MANAGEMENT INC.

Defendants to the Counterclaim

STATEMENT OF DEFENCE AND COUNTERCLAIM

COUNTERCLAIM

48. The Plaintiff by Counterclaim, 2047330, claims:

(a) as against the Defendants by Counterclaim, the Mayor and the Town:

(i) damages in the amount of $20,000,000.00 for conspiracy, abuse of public authority, abuse of public office, injurious falsehood, intentional interference with economic relations, breach of contract and breach of privacy;

(b) as against the Defendant by Counterclaim, Borealis:

(i) damages in the amount of $20,000,000.00 for conspiracy, breach of contract and breach of confidence;

(c) as against all Defendants by Counterclaim:

(i) punitive damages in the amount of $1,000,000.00;

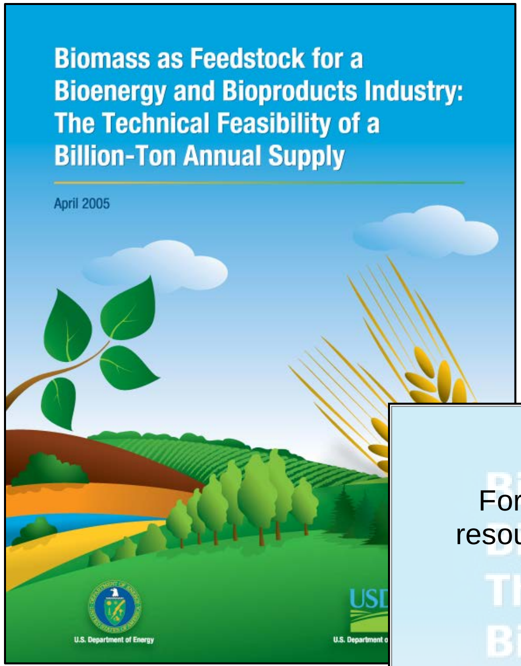
Moral of the story:
Don't try to sell BIOCHAR in Ajax

USDA

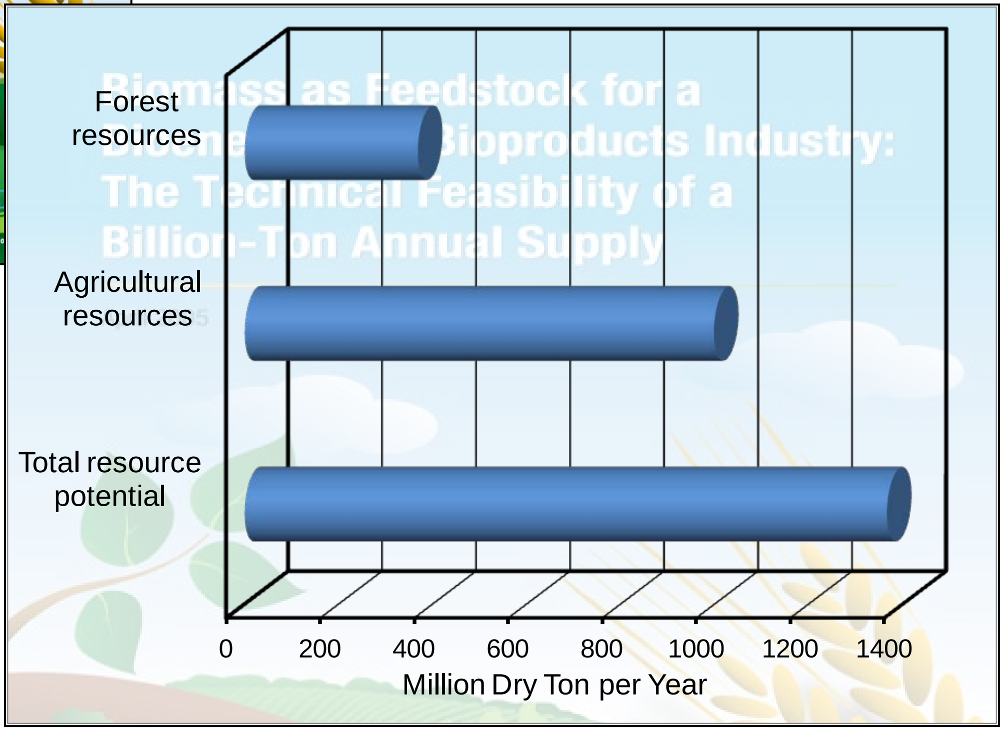
Advantages & Opportunities for Biochar

- Advantages
  - Good information about raw materials
  - Easy concept to accept
  - On the radar and in the news
  - Classification progress
- Opportunities
  - Stability
  - High cost and low value of carbon
  - Sustainability
- Benefits

Advantage – Biochar raw materials



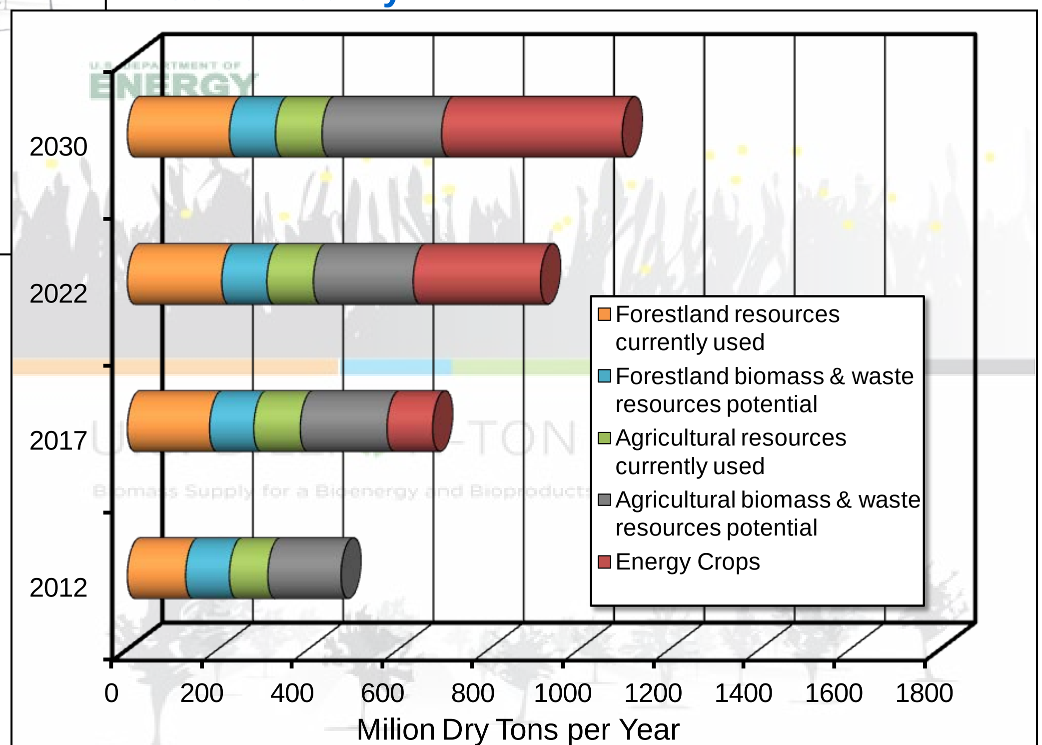
"The purpose of this report is to determine whether the land resources of the United States are capable of producing a sustainable supply of biomass sufficient to displace 30 percent or more of the country's present petroleum consumption – the goal set by the Advisory Committee in their vision for biomass technologies. **Accomplishing this goal would require approximately 1 billion dry tons of biomass feedstock per year.**"



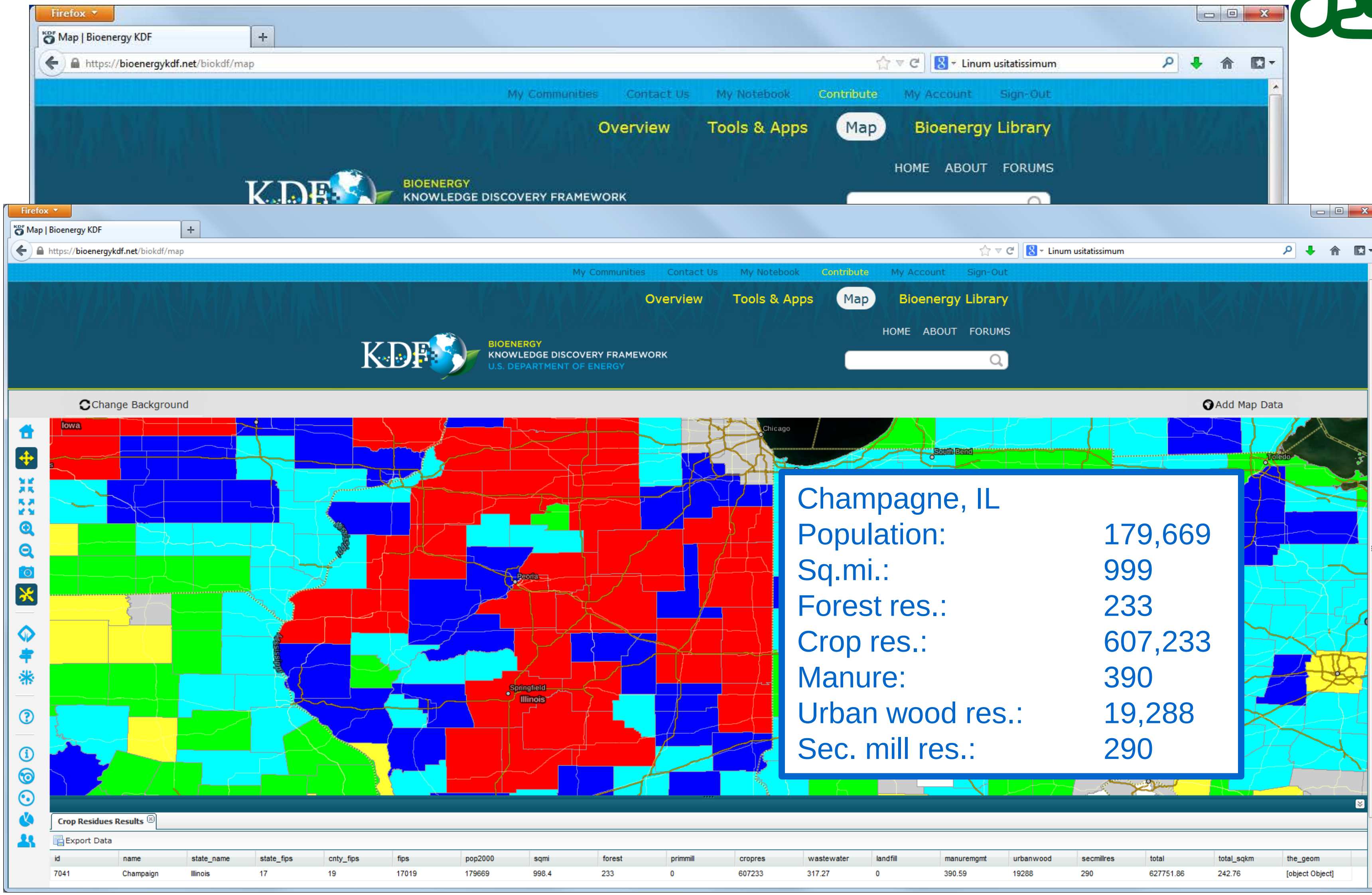
Advantage – Biochar raw materials update

"In addition to updating the 2005 study, this report attempts to address a number of its shortcomings. Specifically, the update provides:

- A spatial, **county-by-county inventory** of primary feedstocks
- **Price and available** quantities (e.g., supply curves) for the individual feedstocks
- A more rigorous treatment and modeling of **resource sustainability**."

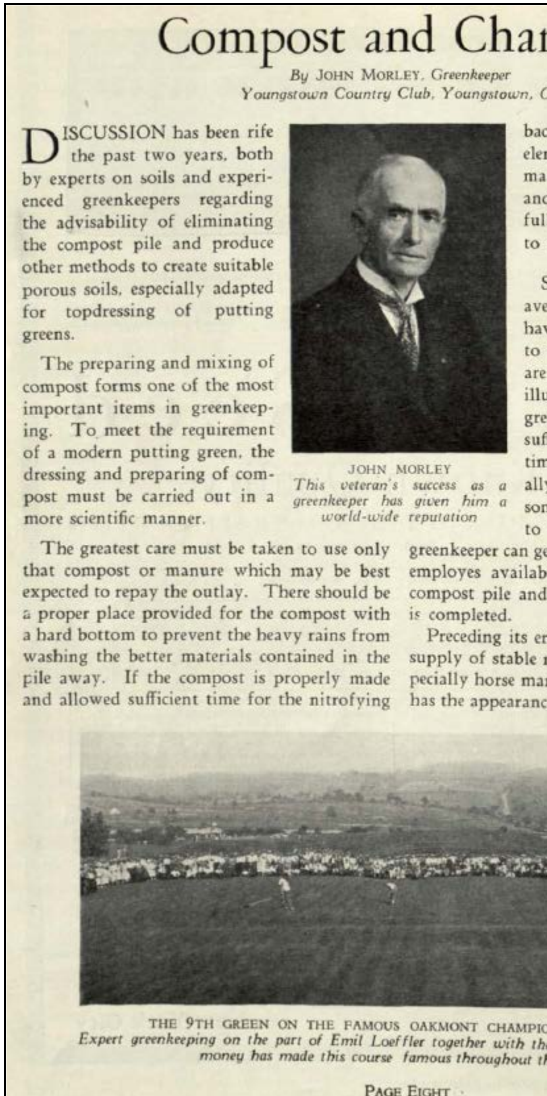


Advantage – Bioenergy KDF database



bioenergykdf.net

Easy concept to accept (biochar for lands)



Compost and Char

By JOHN MORLEY, Greenkeeper
Youngstown Country Club, Youngstown, O

DISCUSSION has been rife the past two years, both by experts on soils and experienced greenkeepers regarding the advisability of eliminating the compost pile and produce other methods to create suitable porous soils, especially adapted for topdressing of putting greens.

The preparing and mixing of compost forms one of the most important items in greenkeeping. To meet the requirement of a modern putting green, the dressing and preparing of compost must be carried out in a more scientific manner.

JOHN MORLEY
This veteran's success as a greenkeeper has given him a world-wide reputation

The greatest care must be taken to use only that compost or manure which may be best expected to repay the outlay. There should be a proper place provided for the compost with a hard bottom to prevent the heavy rains from washing the better materials contained in the pile away. If the compost is properly made and allowed sufficient time for the nitrofying

THE 9TH GREEN ON THE FAMOUS OAKMONT CHAMPIO
Expert greenkeeping on the part of Emil Loeffler together with th
money has made this course famous throughout th

PAGE EIGHT

"PERSONALLY, I have realized by using charcoal that it helps to keep the surface of the putting greens in a good porous condition so that when the player makes a good shot to the putting green the ball will bite well and not bounce off the green. We often create this condition by the use of charcoal, especially where silt and clay loams predominate. During the playing season, should it be a dry one, charcoal helps to prevent the surface of the soil from baking and cracking open, thus preventing the nitrogen gases from escaping out of the soil. After a heavy rain or watering charcoal expands, thus allowing more water to enter into the subsoil. Charcoal also helps to make the surface of the putting greens firm and porous. For illustration (and don't think this is a fish story), a year ago in the early part of the month of May our clubhouse was destroyed by fire. I had a large practice green situated close to the clubhouse. A huge fire engine drove across the middle of the green and it did not destroy a square inch of sod. I have counted at least twenty women with high heeled shoes walk across this green and they never leave any evil effects. I have never raised a divot on any of our short holes in two years and never have had a single complaint. The chief cause of maintaining a good firm surface I attribute to the liberal amount of charcoal in my putting greens."

The Plough, the Loom and the Anvil 3(10):625-626, 1851

The National Greenkeeper, Sept. 1929

On the radar and in the news

FROM THE APRIL 2007 ISSUE

Black Gold of the Amazon

Precious soil could save the rainforest and combat global warming.

By Michael Tennesen | Monday, April 30, 2007

RELATED TAGS: ARCHAEOLOGY, AGRICULTURE, GLOBAL WARMING, ECOSYSTEMS, RAINFOREST

Like 14 Tweet 3 +1 0 Share 27

On August 13, 2005, American archaeologist James Petersen,Brazilian archaeologist Eduardo Neves, and two colleagues pulled up toa restaurant on a jungle road near Iranduba in the Brazilian Amazon tohave a beer. At about 6:45 p.m., two young men, one brandishing a .38revolver, entered the restaurant and demanded the patrons' money. Thearchaeologists turned over their money and the bandits started toleave. Then, almost as an afterthought, one of them shot Petersen inthe stomach. Neves and the others raced Petersen to the hospital, buttheir friend bled to death before they could reach help.

State and municipal police reacted quickly to the news, cordoned offroads, and brought suspects to the restaurant for identification.Within 24 hours the police had arrested the two armed bandits and theirdriver and learned there were two others involved. The crime wasfront-page news in Manaus, the capital of the state, a city of morethan a million about an hour north of the study site, across the RioNegro. After a 21-day manhunt through the jungle, the remaining twofugitives were captured, and when the state police brought thecriminals back, the Iranduba chief of police, Normando Barbosa, says,"there were hundreds of people lined up on the road that wanted tolynch the killers."

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p in soil makes more ser

Lehmann. Can this idea

Black Is the New Green

In a deft act of ecological jujitsu, Johannes Lehmann wants to borrow an 8,000-year-old technology to interrupt the natural carbon cycle and return some of the infamous black stuff to the soil.

More Options

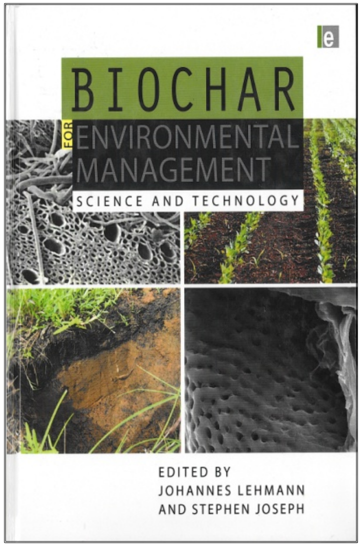
By Carl Zimmer

Win-win solutions can be hard to come by. But if Cornell University soil scientist Johannes Lehmann is right, there may be a way to lower our emission of heat-trapping greenhouse gases, save millions of people's lives, and significantly boost the productivity of the world's farms—all at the same time. And, most remarkably, his strategy is based on a deceptively simple technology invented 8,000 years ago.

Lehmann's idea starts with organic leftovers that people normally burn or leave to rot—forest brush, corn husks, nutshells, and even chicken manure. When this stuff decays or goes up in smoke, it releases vast amounts of heat-trapping carbon into the atmosphere. Lehmann's plan is to short-circuit this carbon cycle by creating a material called biochar. Making biochar involves heating this organic matter without oxygen in a process called pyrolysis. It can be carried out in a small household stove, or it can be an industrial operation. Either way, the pyrolysis doesn't produce carbon dioxide as ordinary, oxygen-fueled fire does. Instead, the carbon gets locked up in black chunks of charcoal-like matter.

It does not hurt…

Advantage – Biochar classification/analysis



Total C, H, O
- High (>80%), Medium (60-80%), Low (20-60%) C

Labile (and stabile C)
- Dissolves in water, decomposes at 350°C, decomposes at 950°C

Element other than C, H, O
- S and N from ultimate analysis, metals from ash dissolution

Surface area and pore-size distribution
- Macropore/Micropore ratio

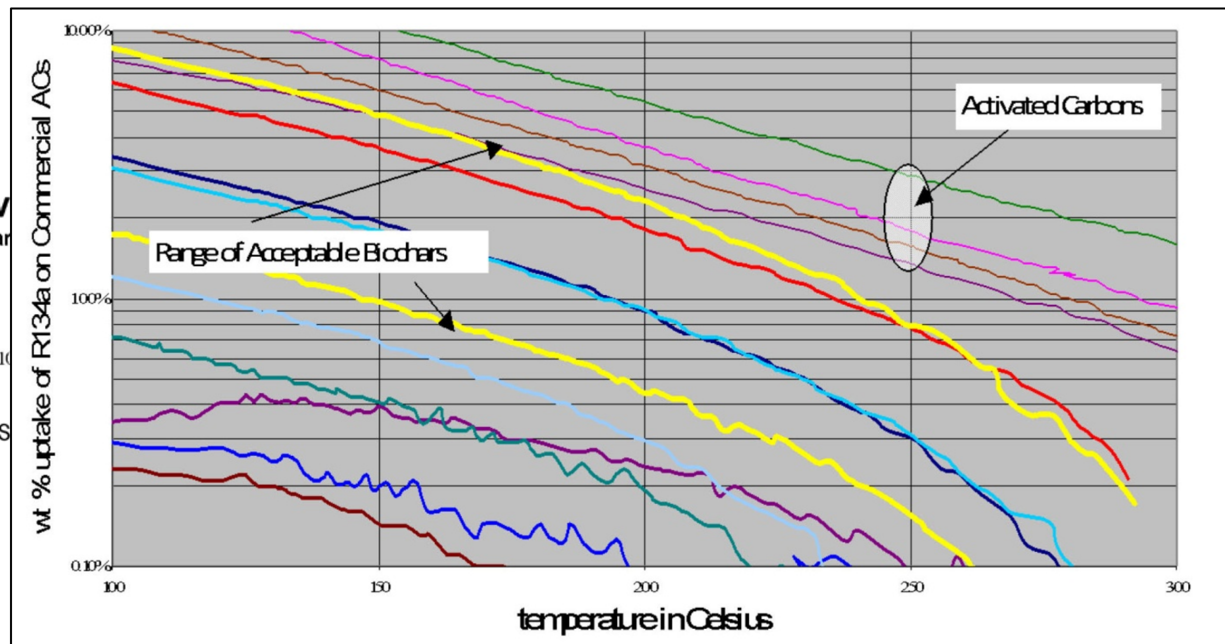
Cation-exchange capacity
- Alternate absorption of ammonium and potassium

Schenkel and Shenxue rev

- implications on char production and biochar

Version 1 (June 2010) issued at the
Biochar2010 Conference, Ames, Iowa – June 201

Hugh McLaughlin, PhD, PE[1] and Frank E. S



Advantage – Biochar classification

International Biochar Initiative

Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil

Type of Document:
Status of Document:
Version Number:
Version Date:
Original Date:
Document Reference Co

NOTE TO USERS:
The International Biocha
are using the latest vers
http://www.biochar-inte

Standardized Product Definit Standards)

Feedstock

Biomass and diluents (<10%). <2% contaminants. No municipal solid waste or hazardous waste.

Test Category A - Basic Utility Properties (required)

Particle size, moisture

Brand Name →	**GOOD GROW BIOCHAR**	
	MATERIAL TYPE	Biochar made from declared feedstock
	COUNTRY OF ORIGIN	Australia
	COUNTRY OF USE	Australia
	FEEDSTOCK COUNTRY OF ORIGIN	Australia
	FEEDSTOCK TYPE	Processed Feedstock
Ingredients →	FEEDSTOCK COMPOSITION DECLARATION	poultry manure - 83%, wood chip bedding - 17%
Test Category A →	**BIOCHAR BASIC UTILITY PROPERTIES**	
	Moisture (at time of analysis)	20% - DECLARATION
	Organic Carbon	42% - CLASS 2 BIOCHAR
	$H:C_{org}$	0.6 - PASS
	Total Ash	40% - DECLARATION
	Total N	5.4% - DECLARATION
	pH	7.5 - DECLARATION
	Electrical Conductivity	7.3 dS/m - DECLARATION
	Liming	23% $CaCO_3$
	Particle Size Distribution	5% <420μm; 35% 420-2,380 μm; 45% 2,380-4,760 μm; 15% >4,760 μm
Test Category B →	**TOXICANT ASSESSMENT**	
	Germination Inhibition Assay	PASS
	Polycyclic Aromatic Hydrocarbons (PAHs)	6 mg /kg - PASS

	Dioxin/Furan (PCDD/Fs)	0.02 ng/kg I-TEQ - PASS
	Polychlorinated Biphenyls (PCBs)	0.2 mg/kg - PASS
	Arsenic	10 mg/kg - PASS
	Cadmium	1.2 mg/kg - PASS
	Chromium	60 mg/kg - PASS
	Cobalt	14 mg/kg - PASS
	Copper	143 mg/kg - PASS
	Lead	125 mg/kg - PASS
	Mercury	0.5 mg/kg - PASS
	Molybdenum	5 mg/kg - PASS
	Nickel	25 mg/kg - PASS
	Selenium	10 mg/kg - PASS
	Zinc	320 mg/kg - PASS
	Boron	20 mg/kg- DECLARATION
	Chlorine	90 mg/kg- DECLARATION
	Sodium	140 mg/kg- DECLARATION
Test Category C →	**BIOCHAR ADVANCED ANALYSIS AND SOIL ENHANCEMENT PROPERTIES**	
	Mineral N (ammonium and nitrate)	21 mg/kg - DECLARATION
	Total P&K	3.1% P, 4.4%K - DECLARATION
	Available P	16 mg/kg - DECLARATION
	Volatile Matter	6.8% - DECLARATION
	Total Surface Area	790 m2/g- DECLARATION
	External Surface Area	160 m2/g- DECLARATION
Net Weight →	**Net Weight – 25 lbs (11.33kg)**	
Name and → Address of Manufacturer	Good Grow Biochar Company	
	123 County Route 1	
	Centerville, Any State, USA	
	Please see attached MSDS documentation for appropriate shipping, handling, and storage procedures.	

USDA

Advantage – Long term stability is certain

Naturwissenschaften (2001) 88:37–41
DOI 10.1007/s001140000193

SHORT COMMUNICATION

Biogeosciences, 3, 397–420, 2006
www.biogeosciences.net/3/397/2006/

Available online at www.sciencedirect.com
ScienceDirect
Geochimica et Cosmochimica Acta 72 (2008) 6069–6078
www.elsevier.com/locate/gca

Stability of biomass-derived black carbon in soils

Biqing Liang [a], Johannes Lehmann [a,*], Dawit Solomon [a], Saran Sohi [b], Janice E. Thies [a], Jan O. Skjemstad [c], Flavio J. Luizão [d], Mark H. Engelhard [e], Eduardo G. Neves [f], Sue Wirick [g]

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[b] Department of Soil Science, Rothamsted Research, Harpenden AL5 2JQ, UK
[c] CSIRO Land and Water, Glen Osmond, SA 5064, Australia
[d] Instituto Nacional de Pesquisa da Amazônia (INPA), 69011-970 Manaus, Brazil
[e] Environmental Molecular and Sciences Laboratory, Pacific Northwest National Laboratory, Richland, WA 99352, USA
[f] Museu de Arqueologia e Etnologia, Universidade de São Paulo, São Paulo, SP 05508-900, Brazil
[g] Department of Physics and Astronomy, State University of New York at Stony Brook, Stony Brook, NY, USA

Received 29 May 2008; accepted in revised form 25 September 2008; available online 8 October 2008

Abstract

Black carbon (BC) may play an important role in the global C budget, due to its potential to act as a significant sink of atmospheric CO_2. In order to fully evaluate the influence of BC on the global C cycle, an understanding of the stability of BC is required. The biochemical stability of BC was assessed in a chronosequence of high-BC-containing Anthrosols from the central Amazon, Brazil, using a range of spectroscopic and biological methods. Results revealed that the Anthrosols had 61–80% lower ($P < 0.05$) CO_2 evolution per unit C over 532 days compared to their respective adjacent soils with low BC contents. No significant ($P > 0.05$) difference in CO_2 respiration per unit C was observed between Anthrosols with contrasting ages of BC (600–8700 years BP) and soil textures (0.3–36% clay). Similarly, the molecular composition of the core regions of micrometer-sized BC particles quantified by synchrotron-based Near-Edge X-ray Fine Structure (NEXAFS) spectroscopy coupled to Scanning Transmission X-ray Microscopy (STXM) remained similar regardless of their ages and closely resembled the spectral characteristics of fresh BC. BC decomposed extremely slowly to an extent that it was not possible to detect chemical changes between youngest and oldest samples, as also confirmed by X-ray Photoelectron Spectroscopy (XPS). Deconvolution of NEXAFS spectra revealed greater oxidation on the surfaces of BC particles with little penetration into the core of the particles. The similar C mineralization between different BC-rich soils regardless of soil texture underpins the importance of chemical recalcitrance for the stability of BC, in contrast to adjacent soils which showed the highest mineralization in the sandiest soil. However, the BC-rich Anthrosols had higher proportions (72–90%) of C in the more stable organo-mineral fraction than BC-poor adjacent soils (2–70%), suggesting some degree of physical stabilization.

Opportunity – To predict the future….of carbon

Schenkel and Shenxue revisited

es

International Biochar Initiative

Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil

Type of Document:	Product Definition and Specification Standards
Status of Document:	Final
Version Number:	1.1
Version Date:	11 April 2013
Original Date:	10 January 2011 for Public Posting
Document Reference Code:	IBI-STD-01.1

NOTE TO USERS:
The International Biochar Initiative may update this manual as necessary. Please make sure you are using the latest version available at http://www.biochar-international.org/characterizationstandard.

Labile (and stabile C)

Dissolves in water, decomposes at 350°C, decomposes at 950°C

$$C_t = C_{labile,t=0}\, e^{-k_{labile}\,t} + C_{stabile,t=0}\, e^{-k_{stabile}\,t}$$

McShields Biochar Characterization Procedure

(1) Dry at 200°C, (2) pyrolysis at 450°C, (3) ash part of (2) at 550°C
(2)-(1) is mobile matter and (2)-(3) is resident matter
Determine C & N on (1) and (2). Assume Total – C = OH

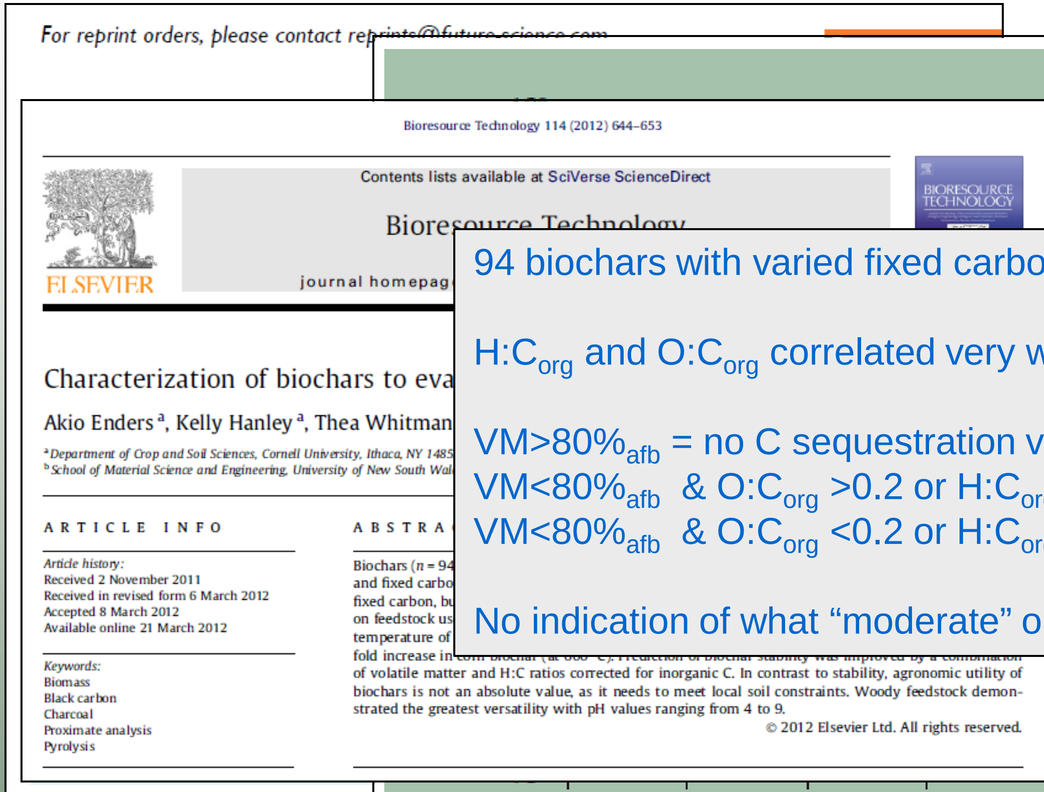
Mobile is mobile, resident is stable

Test Category A - Basic Utility Properties (required)

C_{inorg}, C_{org} (C_{tot}-C_{inorg}), H, N, ash, (H:C_{org})

$$H{:}C_{org} < 0.7$$

Opportunity – Predicting stability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Bioresource Technology 114 (2012) 644–653

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journal homepage

Characterization of biochars to eva

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Black carbon
Charcoal
Proximate analysis
Pyrolysis

ABSTRA

Biochars (n = 94 ... and fixed carbo ... fixed carbon, bu ... on feedstock us ... temperature of ... fold increase in ... of volatile matter and H:C ratios corrected for inorganic C. In contrast to stability, agronomic utility of biochars is not an absolute value, as it needs to meet local soil constraints. Woody feedstock demonstrated the greatest versatility with pH values ranging from 4 to 9.

94 biochars with varied fixed carbon, volatile matter, and ash content

$H:C_{org}$ and $O:C_{org}$ correlated very well with ash-free volatile matter

$VM>80\%_{afb}$ = no C sequestration value
$VM<80\%_{afb}$ & $O:C_{org}$ >0.2 or $H:C_{org}$ >0.4 = moderate C sequestration
$VM<80\%_{afb}$ & $O:C_{org}$ <0.2 or $H:C_{org}$ <0.4 = high C sequestration

No indication of what “moderate” or “high” C sequestration was

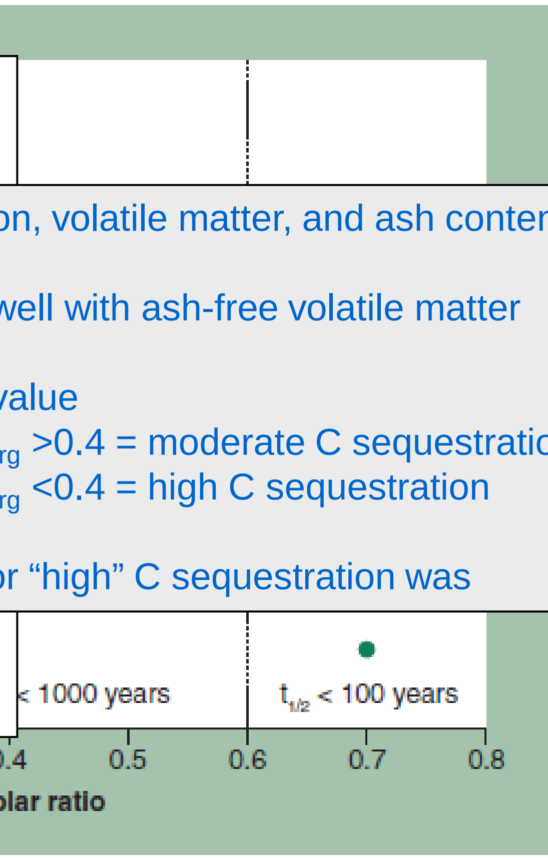

Figure 5. Correlation of the oxygen to carbon (O:C) molar ratio and predicted half-life of synthetic biochar in various laboratory incubations from the literature studies presented in Table 2 **(n = 35).** The sole exception to these divisions were biochars from Hamer *et al.*; shown in the rectangle [94].

Opportunity – Predicting stability

Organic Geochemistry 42 (2011) 1331–1342

Contributi

R. Calvelo Pe
F. Macías [c], J.

Organic Geochemistry 60 (2013) 40–44

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GLOBAL CHANGE BIOLOGY BIOENERGY

GCB Bioenergy (2013) 5, 122–131, doi: 10.1111/gcbb.12030

The effect of pyrolysis conditions on biochar stability as determined by three methods

KYLE CROMBIE, ONDŘEJ MAŠEK, SARAN P. SOHI, PETER BROWNSORT and ANDREW CROSS

UK Biochar Research Centre, School of GeoSciences, University of Edinburgh, Crew Building, King's Buildings, Edinburgh, EH9 3JN, UK

Abstract

Biochar is the porous, carbonaceous material produced by thermochemical treatment of organic materials in an oxygen-limited env… decomposition, and… potential of differen… assessing biochar st… ratio; however, non… three feedstocks (P… heating rates (5 and… ysis, ultimate analy… Edinburgh accelerated ageing tool (Edinburgh stability tool). As expected, increased pyrolysis temperatures resulted in higher fractions of stable C and total C due to an increased release of volatiles. Data from the Edinburgh stability tool were compared with those obtained by the other methods, i.e. fixed C, volatile matter, O : C and H : C ratios, to investigate potential relationships between them. Results of this comparison showed that there was a strong correlation ($R > 0.79$) between the stable C determined by the Edinburgh stability tool and fixed C, volatile matter and O : C, however, H : C showed a weaker correlation ($R = 0.65$). An understanding of the influence of feedstock and production conditions on the long-term stability of biochar is pivotal for its function as a C mitigation measure, as production and use of unstable biochar would result in a relatively rapid return of C into the atmosphere, thus potentially intensifying climate change rather than alleviating it.

Keywords: biochar, carbon sequestration, Edinburgh toolkit, physiochemical properties, pyrolysis, stability determination, stable carbon

Received 4 September 2012 and accepted 30 September 2012

Edinburgh Stability Tool

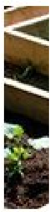
Oxidation with H_2O_2 at 80°C predicts labile C that will degrade in 50-250 years

The stabile C correlated well with Fixed C and O:C

Cost of biochar

$4,440/ton

$21,730/ton



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Biochar Enhanced Soil Amendment (1/2 Cu. Ft.)
by Biochar Enhanced Soil Amendment (1/2 Cu. Ft.)

Biochar UHP -(Ultra High Porosity)- 5 Gallons
by Charfecta
Be the first to review this item

Price: $113.33

In stock.
Processing takes an additional 4 to 5 days for orders from this seller.
Ships from and sold by **Charfecta**.

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- Enhanced plant growth
- Reduced fertilizer requirement
- Reduced leaching of nutrients
- Stored carbon in a long term stable sink
- Improved soil water handling characteristics

- provides a natural carbon source, minimizes nutrient leaching, reduces soil acidity.
- Use in your garden, lawn or landscape projects, or add to houseplants.

to
hat's

- Thank you for choosing carbon negative soils. We appreciate your continued support and please let us know if we can do anything to improve your experience.

Opportunity – Reduce the cost of biochar

Crop	M acres	$/acre	Biomass $/acre	Recovery (yr)
Corn	87.4	1,081	2,228	7
Soybeans	76.1	658	2,228	11
Hay	56.3	376	2,228	20
Wheat	49.0	365	2,228	21
Cotton	9.4	858	2,228	9
Grain sorghum	5.0	410	2,228	18
Barley	3.2	445	2,228	17
Sunflower	1.8	474	2,228	16
Canola	1.7	399	2,228	19

%

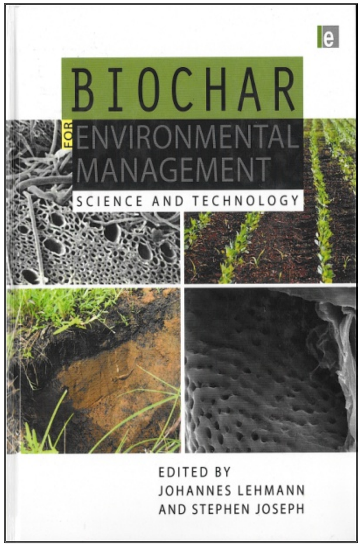
gher yield

CO_2 Credit

2.75 ton CO_2e/ton char

$4/ton CO_2e

Detail cost analysis



19

Economics of Biochar Production, Utilization and Greenhouse Gas Offsets

350 BIOCHAR FOR ENVIRONMENTAL MANAGEMENT

Table 19.6 *Returns and costs (US\$ t^{-1} feedstock) as well as biochar yields (t t^{-1} feedstock) for fast and slow pyrolysis as value items are applied*

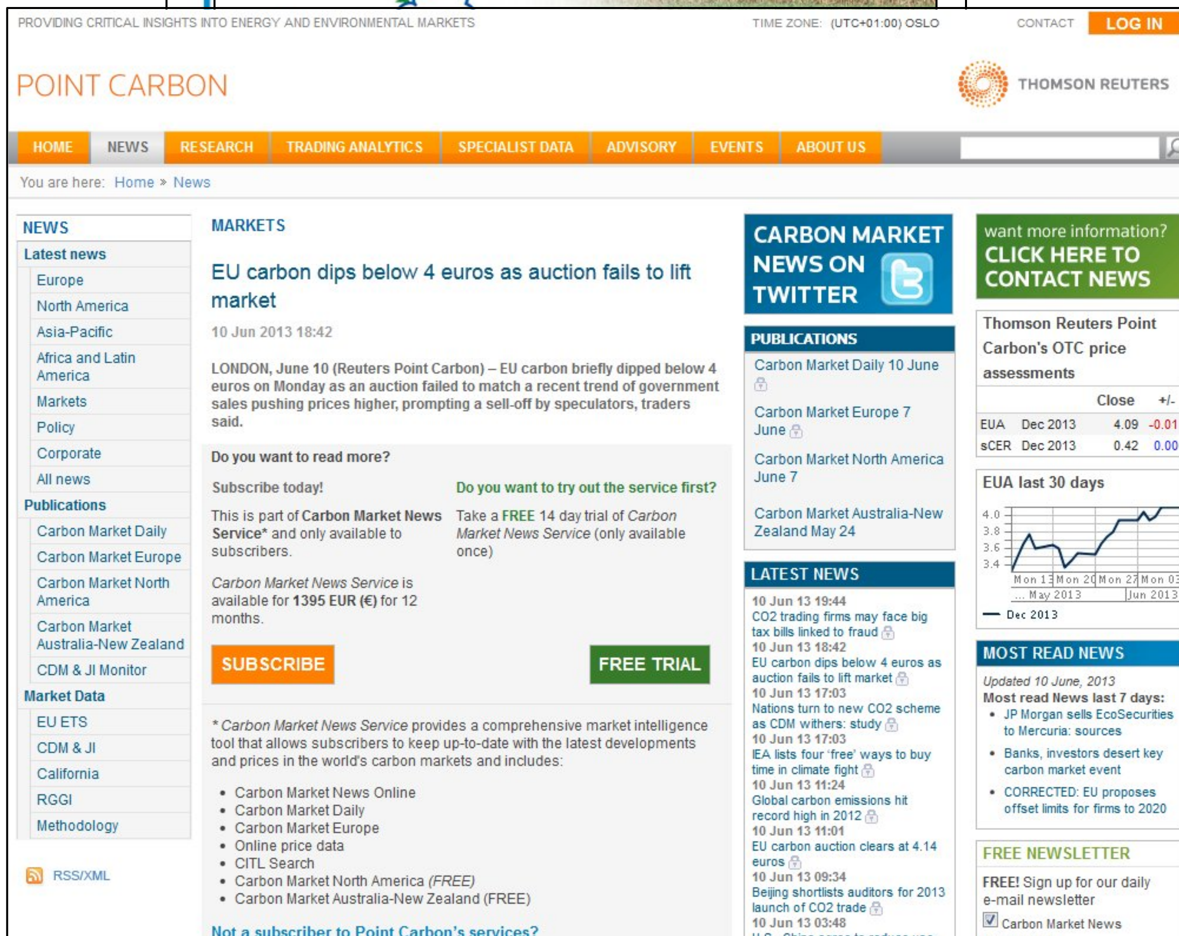
	Fast	Slow
Feedstock cost	–\$59.44	–\$59.44
Pyrolysis cost (modules I and II)	–\$46.82	–\$42.05
Generating cost (module III)	–\$43.26	–\$10.81
Electricity value	\$100.00	\$25.00
Net margin (electricity only)	–\$49.52	–\$87.30
Biochar yield	0.045	0.350
Biochar value	\$2.00	\$15.75
Biochar haul cost	\$0.39	\$3.07
Net margin (electricity + biochar)	–\$47.91	–\$74.63
GHG value	\$3.29	\$4.55
Net margin all	–\$44.62	–\$70.08

Source: chapter authors

Fast pyrolysis require \$58/ton CO_2e
Slow pyrolysis require \$71/ton CO_2e
(base case \$4/ton CO_2e)

Low value of carbon (credit)

Fast pyrolysis require \$58/ton CO_2e to be profitable
Slow pyrolysis require \$71/ton CO_2e to be profitable
(base case \$4/ton CO_2e)



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MARKETS

EU carbon dips below 4 euros as auction fails to lift market

10 Jun 2013 18:42

LONDON, June 10 (Reuters Point Carbon) – EU carbon briefly dipped below 4 euros on Monday as an auction failed to match a recent trend of government sales pushing prices higher, prompting a sell-off by speculators, traders said.

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Thomson Reuters Point Carbon's OTC price assessments

		Close	+/-
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sCER	Dec 2013	0.42	0.00

EUA last 30 days

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Updated 10 June, 2013

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Carbon Market News

It is a far cry from the \$25 a tonne forecast when the emissions trading scheme (ETS) was created.

\$4.80/ton CO_2e

Dropped to \$0.10/ton from forecast \$18/ton CO_2e

Opportunity – Sustainability

Crop	Ton residue/acre	Ton SP Char/acre	Ton FP Char/acre
Corn	23.3	8.1	1.05
Soybeans	0.3	0.1	0.01
Wheat	10.8	3.8	0.49
Cotton	1.7	0.6	0.08
Grain sorghum	10.1	3.5	0.45
Barley	13.2	4.6	0.59

Biochar
35% yield for Slow P
4.5% yield for Fast P

Application Rates (8”)
6.5 ton/acre = 0.5%
13 ton/acre = 1%

Benefits – Final thoughts

are appended to this work, spare me all further remarks upon its efficacy.

Plants thrive in powdered c
brought to blossom and bear
the influence of the rain and t
charcoal may be previously
Charcoal is the most "indiffe
changeable substance known ;
centuries without change, and
ject to decomposition. The o
it can yield to plants are some
tains, amongst which is silica
known, however, to possess the
gases within its pores, and partic
And it is by virtue of this pow
plants are supplied in charcoal
with an atmosphere of carboni
is renewed as quickly as it is a

In charcoal powder, which
this purpose by *Lukas* for sev
found a brown substance solub
substance was evidently due t
the roots of the plants which g

A plant placed in a closed
air, and therefore the carbo
renewed, dies exactly as it would do in the vacuum of an air-pump, or in an atmosphere of nitrogen or carbonic acid, even though its roots be fixed in the richest mould.

"Plants thrive in powdered charcoal, and may be brought to blossom and bear fruit if exposed to the influence of the rain and the atmosphere; the charcoal may be previously heated to redness. Charcoal is the most "indifferent" and most unchangeable substance known; it may be kept for centuries without change, and is therefore, not subject to decomposition. The only substances which it can yield to plants are some salts, which it contains, among which is silicate of potash."

Justus Liebig, M.D., Ph.D., F.R.S., M.R.I.A., "Organic Chemistry and its Application to Agriculture and Physiology," p. 62, 1840.